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Monitoring Learning in Nursing using the Electroencephalogram and Intrinsic Motivation Inventory–IMI

Monitorización del aprendizaje en enfermería mediante el electroencefalograma y el Inventario de Motivación Intrínseca–IMI

Karen Cardoso[1,⋆], Milton Antônio Zaro[1]

[1] *Universidade Federal do Rio Grande do Sul - UFRGS/ Programa de Pós-graduação em Informática na Educação (PPGIE)-Porto Alegre, Brasil.*

Abstract.
The objectives of this study were to develop the Laboratory of Immersive Learning in Health and Nursing - LIASE, based on the main themes of biosafety in health, and to evaluate the learning process of undergraduate nursing students from a public federal university through portable Electroencephalogram (EEG) Emotiv Insight 2.0, observation, and Intrinsic Motivation Inventory. The present research contains a qualitative-quantitative, exploratory, and experimental methodology from a pilot virtual laboratory, developed in the Immersive Virtual World – IVW, represented in this study by Second Life – SL. The sample consisted of 17 students who agreed with the inclusion criteria of the study. Among them, 9 students had stable EEG signals. Those students were observed during the monitoring of brain activity by the EEG, and at the end of the proposed learning pathway, they filled out the Intrinsic Motivation Inventory (IMI). The results were obtained through triangulation of the different collection instruments and the following variables: Stress, Enthusiasm/Excitement, Engagement, Focus/attention, and Relaxation, measured and verified by the Emotiv algorithm's brain wave analysis, which algorithm which correspond to the metrics of brain performance.

Resumen.
Los objetivos de este estudio fueron desarrollar el Laboratorio de Aprendizaje Inmersivo en Salud y Enfermería - LIASE, basado en los principales temas de bioseguridad en salud, y evaluar el proceso de aprendizaje de estudiantes de enfermería de pregrado de una universidad pública federal a través del Electroencefalograma (EEG) portátil Emotiv Insight 2.0, observación e Inventario de Motivación Intrínseca. La presente investigación contiene una metodología cualitativa-cuantitativa, exploratoria y experimental, a partir de un laboratorio virtual piloto, desarrollado en el Mundo Virtual Inmersivo – IVW, representado en este estudio por Second Life – SL. La muestra estuvo compuesta por 17 estudiantes que estuvieron de acuerdo con los criterios de inclusión del estudio. Entre ellos, 9 estudiantes tenían señales EEG estables. Esos estudiantes fueron observados durante el monitoreo de la actividad cerebral por el EEG, y al final de la ruta de aprendizaje propuesta, llenaron el Inventario de Motivación Intrínseca (IMI). Los resultados se obtuvieron a través de la triangulación de los diferentes instrumentos de recolección y las siguientes variables: Estrés, Entusiasmo/Excitación, Compromiso, Enfoque/atención y Relajación, medidas y verificadas mediante el análisis de ondas cerebrales del algoritmo Emotiv, algoritmo que corresponde a las métricas de rendimiento cerebral.

Keywords.
Biological Risk Containment, Nursing Education, Virtual Labs, Neuroeducation, Simulation Training.

Palabras Clave.
Contención de riesgo biológico, educación en enfermería, laboratorios virtuales, neuroeducación, entrenamiento con simulación.

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⋆**Corresponding author**:
Karen Cardoso
Email: karen.caetano@gmail.com

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1. Introduction

The main objective of this study was to establish the Virtual Immersive Learning Laboratory for Health and Nursing (LIASE). To achieve this, the study closely monitored and tracked learning activities utilizing the Electroencephalogram (EEG) technique. The research team also identified cognitive performance metrics and assessed the intrinsic motivation (IMI) of the study participants upon completion of the learning route. By simulating various situations and practices, the study aimed to trigger responses and activate different brain areas. This approach has been shown to be effective in facilitating the learning process and enhancing knowledge retention (Cardoza, 2011).

Monitoring students' brain activity using the electroencephalogram (EEG) during simulated virtual learning processes can help us understand what happens to the brain. Studies of this kind are essential to improve the use of these virtual tools.

In order to optimize educational methods, it is imperative to have a thorough understanding of how the brain mobilizes and learns through observation of brain activity in simulated environments, clinical settings, and virtual labs. The development of Neuroeducation and research focused on education points to the need to improve educational practices and imaging techniques and the monitoring of brain electrical activity are some of the methods used for educational research (Charland, 2015; Harrison, 2013; Ng, 2018; Xu, 2018).

1.1 Neuroeducation, Brain and Learning

The field of education has seen a significant growth in studies that understand the brain processes involved in learning. This multidisciplinary approach has given rise to a new field called Neuroeducation, which integrates neuroscience, pedagogy, and psychology. Its goal is to explain the behaviors and mental states related to the learning process, identify affected brain areas, and develop educational technology that enhances and maximizes learning (Feiler, 2018; Nunes, 2019; Tokuhama-Espinosa, Zaro, 2008).

Learning is tied to how our brain understands and processes various external and internal stimuli. The perception of emotions encompasses other areas that go beyond the limbic system and impact cognitive and decision-making functions, because although emotional functioning occurs throughout the brain, and not merely in the limbic system (paleomammalian brain), as it is a collaborative neuronal process with other brain areas, particularly the prefrontal and orbitofrontal cortex, emotional functions are obviously interconnected with cognitive and executive functions (Fonseca, 2016).

Monitoring the cognitive mental states of volunteers in different activities has shown the oscillation between focus/attention, engagement, stress, and relaxation, indicating the reaction to different levels of difficulty in carrying out a task or test (Strmiska, 2018).

The identification of attention and emotional states associated with brain waves and verified by EEG can help implement teaching-learning processes with better results for individuals (Langroudi, 2018).

In studies of brain-computer interfaces, the EEG acted as a psychophysiological measure used to obtain emotional/mental cognitive metrics. The electrode sensors were positioned in the frontal lobe of the brain and other positions on the head, according to the area of interest. The analysis of brain waves is advanced in the field of health, but little has been explored in the analysis of educational environments and classrooms, highlighting the importance of further studies in education (Charland, 2015; Harrison, 2013; Xu, 2018).

1.2 Immersive Virtual Worlds in Education

The Immersive Virtual World (IVW) is a three-dimensional space, a graphic environment that represents a physical space, simulating gravity, time, seasons, and even its economy, allowing the user to modify this world. In these virtual spaces, users share a network that has the persistence and synchronicity of other people, who access and populate the MVI and have their connection facilitated by networked computers. Users are represented digitally, constituting their avatar, which allows them to access and interact in the IVW (Bell, 2008; Griol, 2014; Soto, 2013).

The evolution has been growing, indicating the potential of IVMs not only for leisure, but also for the development of educational activities. One of the highlights would be Second Life (SL), which allows the greatest flexibility and customization of the environment, whose multiple resources are private and paid for, and for this reason it has opened space for the development of other open source IVMs, such as OpenSim and Open Wonderland, which have some similarities to SL, yet maintaining the open source multiplatform.

Like SL, Open Sim and Open Wonderland have multiuser access platforms and share a customization of the environment, graphical modeling of 3D objects and interaction with the environment, but they also make it possible to create and share objects and scripts freely (Tarouco, 2020).

The use of virtual simulators provides a safe environment for practicing the skills needed by students and professionals, in contrast to theoretical teaching and practice in traditional laboratories. Traditional laboratories limit students' access to real work situations and the possibility of developing clinical diagnostic skills and dealing with problems without restrictions of space, time, and place. Another aspect to be considered is the feeling of presence, without the pressure of trial and error, which is another possibility that can be positive for students' mental health, where values and ethical aspects must also be present in communication and relationships between avatars (Sloan, 2020; Tsai, 2021, Yang, 2018).

The search for a connection between learning and the activities of brain areas has been the subject of several studies and, in this sense, the changes in brain waves that occur during the learning process monitored by means of a portable Electroencephalogram can validate the Immersive Virtual World – IVW as a tool for learning the decision-making process and mobilizing students' attention (Andersen, 2019; Cardoza, 2011; Murad, 2020; Nunes, 2019; Sloan, 2020; Sportsman, 2021).

The development of LIASE - Health and Nursing Immersive Learning Laboratory, monitoring the learning process, through EEG and the application of the Intrinsic Motivation Inventory to study participants after completing the learning route, are the focus of this study.

2. Methodology

This is a qualitative-quantitative, exploratory, and experimental study of a pilot VM, developed to evaluate the learning process of undergraduate nursing students who voluntarily participated in the research. The students had their brain waves and performance metrics (Engagement, Excitement and Enthusiasm, Focus, Interest, Relaxation and Stress) monitored by EEG during the process of using the LIASE IVM. As for the technical procedures, the study used triangulation of different instruments to collect the participants' learning process (observation, monitoring of brain activity, questionnaire), enabling a greater understanding of the phenomenon studied.

Triangulation is defined as a way of looking at a research topic from at least two perspectives, under equal conditions, with the purpose of broadening the knowledge that a single approach could provide (Flick, 2013).

2.1 Research Subjects

The research subjects were undergraduate nursing students from a public university in Porto Alegre/RS-Brazil, officially registered in the course. The random sample for this study consisted of 17 voluntary participants. The research subjects were chosen because the proposed theme of LIASE is part of the undergraduate curriculum, which is fundamental in the training of nurses throughout the course. The exclusion criteria were previous neurological illness, use of psychoactive medication on a continuous basis or prior to data collection, use of alcohol or drugs on a regular basis and prior to collection, verified during the interview before collection.

The procedures used in this research comply with the criteria of ethics in research with human beings, according to Resolution No. 466/2012 and Resolution No. 510/2016 and with the opinion of the UFRGS ethics and research committee - CAAE - 57500622.3.0000.5347.

2.2 Procedures

The equipment used to monitor the participants' brain activity was the EMOTIV PRO Insight 2. 0 – 5 Channels Mobile Brainwear and its choice took into account the Monitoring the cognitive performance metrics of 34 volunteers in different activities using the Emotiv headset showed the oscillation between focus/attention, engagement, stress and relaxation, indicating the reaction at different levels of difficulty to perform a task or test in Strmiska studies. Other studies with users developing tasks with haptic feedback (controlling a robot on a path with obstacles) report fluctuations in attention, interest, stress and excitement (Mcauley, 1989; Strmiska, 2018).

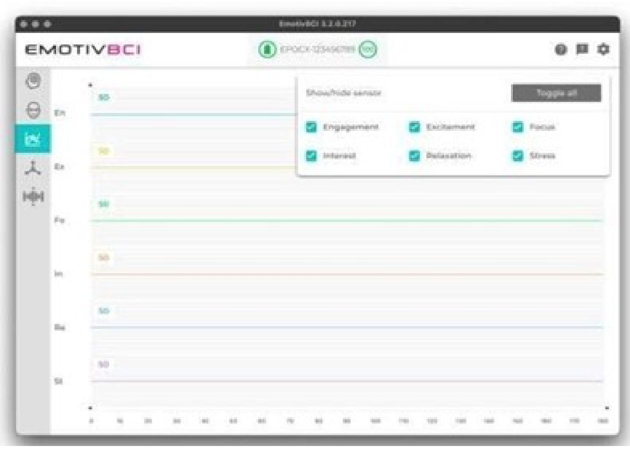
Monitoring the cognitive performance metrics of 34 volunteers in different activities using the Emotiv headset showed the oscillation between focus/attention, engagement, stress and relaxation, indicating the reaction at different levels of difficulty to perform a task or test in Strmiska studies. Other studies with users developing tasks with haptic feedback (controlling a robot on a path with obstacles) report fluctuations in attention, interest, stress and excitement (Mcauley, 1989; Strmiska, 2018).

From the Emotiv library and the algorithm for analyzing the data obtained, pre-processing takes place. Emotiv uses the Brain Computer Interfaces (BCI) software, which is a desktop application for Mac and Windows that allows EMOTIV's data streams to be visualized and trained while monitoring brain activity. The data streams involve mental commands and performance metrics, which allow passive and continuous control based on the participant's real-time cognitive state.

The Performance Metrics data is displayed in the app on an axis scaled from 0 to 100. The graph shows historical data, i.e., the time measurement of the metric during the activity, while the number on the left shows the current value of each metric, as shown in Figure 1.

Figure 1

Graph Showing the Six-performance Metrics



Source: Gitbook-Manual Emotiv. Available at https://emotiv.gitbook.io/insight-manual/

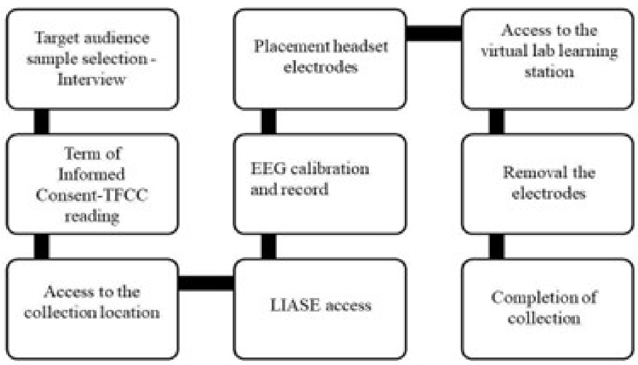
The calibration method is configured in Emotiv and activated at each start of EEG recording and monitoring, corresponding to the participant's eye-opening and closing movements, coordinated by the system.

The psychometric assessment was carried out using the Intrinsic Motivation Inventory (IMI; Mcauley, 1989). The instrument consists of a device that measures the subjective experience of the participants in relation to a target activity, focusing on the assessment of the participants' interest/pleasure, interest and satisfaction, effort, pressure and tension and usefulness.

2.3 Education Flowchart

Figure 2

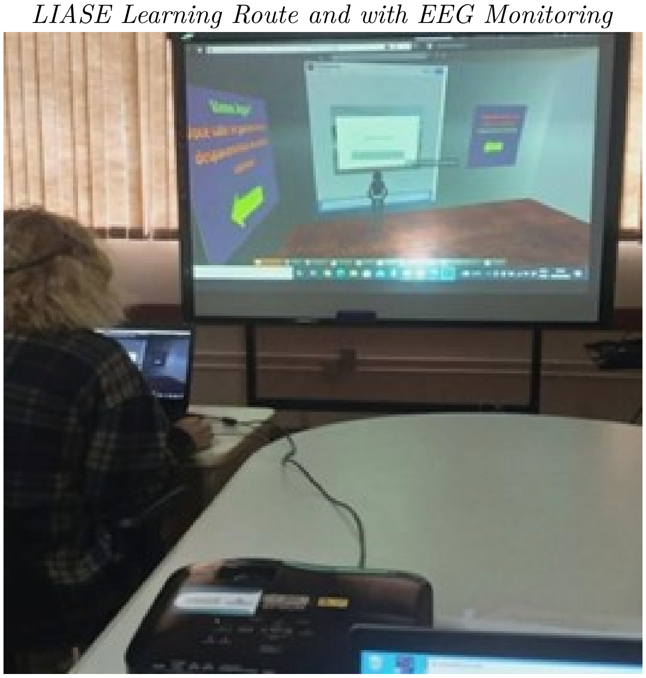
Execution Flowchart



Source: The authors.

Figure 3

One of the Participants Observed During the LIASE Learning Route and with EEG Monitoring



Source: The authors.

3. Results and Discussion

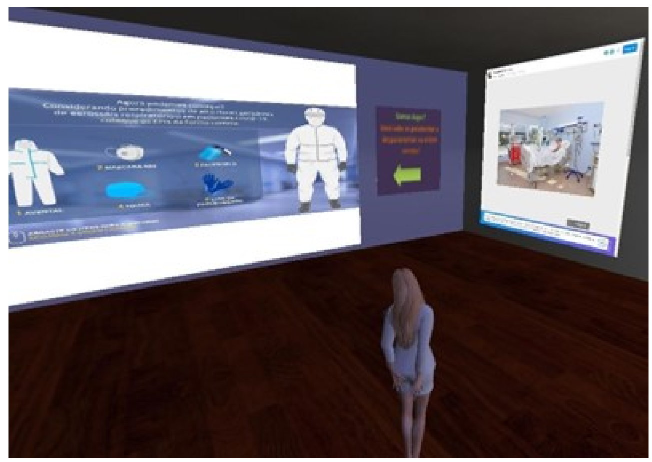
3.1 Educational Prototype

LIASE was developed in SL, with a virtual building and five learning stations. The participant had autonomy and control to develop the proposed activities, which were composed of content, videos, presentations, clickable objects and panels, and games. The learning route with five stations proposed specific activities on the topic of hospital biosafety to participants, as can be seen in Figure 6.

Stations three and four can be seen in figures 4 and 5 respectively, with an avatar in the foreground, the game with specific equipment for COVID-19 cases, the interactive tags contextualizing hospital biosafety actions (Figure 4) and the classification of hospital waste, with games, content and clickable objects (Figure 5).

Figure 4

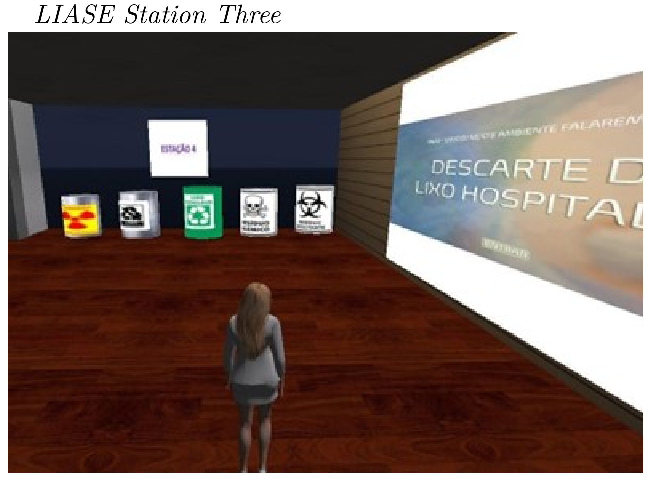
LIASE Station Three



Source: The authors.

Figure 5

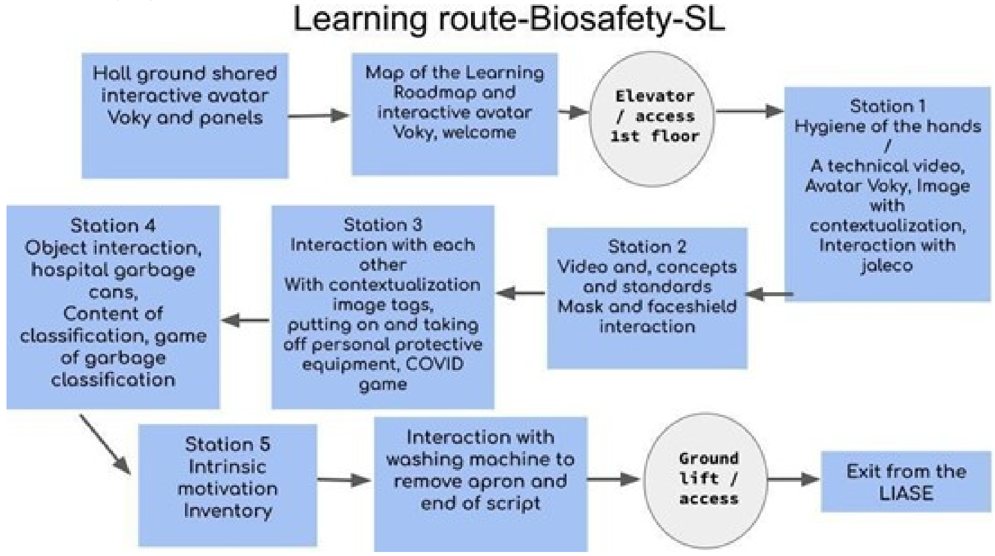
LIASE Station Three



Source: The authors.

Figure 6

Learning Route-Biosafety in Second Life



Source: The authors.

3.2 Results of Monitoring the Learning Process at LIASE by IMI and EEG

After completing the proposed learning script monitored by EEG, 17 participants answered the Intrinsic Motivation Inventory - IMI available on the IVW.

The sample was predominantly female, a characteristic of nursing courses, a profession that still has a higher female representation, with only one participant being male.

Table 1

IMI Results of the 17 Study Participants

Table with the results of the Intrinsic Motivation Inventory (IMI)	
Key Issues	**Results**
Enjoyed the activity	64%
Not nervous	47%
Not aware	5.9%
It was interesting	82.4%
Tense	5.9%
It was fun	58.8%
I felt in control	52.9%
I thought about other things	11.2%
I became immersed in the activity	41.2%
It aroused curiosity	70.6%
I lost track of time	47.1%
It was useful for my education	70.6%
I put a lot of effort into it	17.6%

3.3 Results of the Mental Performance Metrics Verified in the EEG of Five of the Study Participants

Some of the difficulties encountered in the collection were the instability of the internet network, which did not capture signals in some of the activities during its execution. In some cases, recording participants was made impossible; in others, it was necessary to restart, with new calibration. Another aspect verified during the observation of the learning activities was the option of some participants not accessing all the proposed activities and others, on the contrary, going through the learning route more than once.

3.4 Participant 2

Gender: female, semester: 8th, recording time: 1 hour 13 minutes and 8 seconds.

Verification of P2's learning script completion showed levels of engagement, excitement and focus that fluctuate depending on the activity performed. It was a 1 hour and 13-minute recording, where P2 went through and explored the learning script and proposed activities several times. At the end of the recording, local Internet instability occurred, impacting the signal for capturing metrics at the end of the activity.

Peaks of brain activity were detected in P2, as shown in Table 2, which corroborates the results of the IMI completed by the participant and the report of relaxation and absence of stress during the activity and levels above 50 points in large part of the activities performed demonstrating the convergence of the performance metrics found with the participant's report.

Although P2 received guidance before starting the proposed activity and had time to adapt to handling the commands, panels and videos, she reported at IMI feeling a little "lost" in what she was supposed to do, which seems to explain the comings and goings at the different stations, until the activity proposed for P2 made "sense". The course of the learning route was not linear, with some comings and goings between stations.

Table 2

Mental Performance Metrics during Learning Activities – Participant 2

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	53	47	65	32	49	24	64	31	65	31
Excitement	72	72	59	18	41	33	57	73	40	73
Focus	36	40	49	24	42	20	49	19	38	19
Interest	58	32	61	76	61	57	34	71	55	71
Relaxation	21	21	26	42	26	36	25	26	57	26
Stress	33	37	42	36	42	36	35	23	42	23

Source: The authors.

We also observed that P2 maintained high levels of excitement due to the novelty of the activity, but the focus, engagement and interest scores remained stable throughout the entire activity.

3.5 Participant 8

Gender: male, Course: Nursing, Semester: 2nd semester, Recording time: 25 min and 42 sec.

When checking engagement levels, they remained stable for most of the activities' execution time. This means that P8 was in a state of alert and was consciously using attention for stimuli relevant to the task. The P8 engagement score also measures the level of immersion during the activity and, in some activities, increased attention, focus and workload were detected. Engagement is characterized by increased physiological arousal and beta waves, along with attenuated alpha waves. The higher the attention, focus, and workload, the higher the output score reported by Emotiv detection. P8 chose not to watch the video of activity 5, as shown in Table 3.

3.6 Participant 16

Gender: female, course: Nursing, Semester: 8th, Total recording time: 47 min and 29 seconds. Recording P16's performance metrics took three attempts, the first was due to internet signal fluctuations, interfering with the signal, and we did not obtain the metrics. We restarted the recording and, after calibrating the system, we successfully obtained a valid signal of brain activity that, analyzed by the Emotiv algorithm, infers the average performance metric. Verification of completion of the P16 learning script showed levels of engagement, excitement and focus that fluctuate depending on the activity performed.

Technical signal quality issues were generally due to the volume and density of hair, mainly afro, and fluctuations in the university's Internet, leading to the restart of the collection process. When evaluating P16's activity in LIASE, we were able to observe peaks in engagement and interest, especially in playful activities.

We also observed expressive valences in excitement, indicating how much the activity provoked great involvement from the participant and confirming the participant's report in IMI.

Caption – Activities from the Educational Roadmap:

1. Calibration.
2. “Hand hygiene with soap and water video”.
3. Put on the lab coat, “Avatar” guidance moments hand hygiene.
4. Panels “Universal precautions”, “Droplet precautions”, “Respiratory precautions”.
5. “PPE video”.
6. Put on mask and face shield.
7. Interactive tags.
8. PPE game.
9. Hospital waste game.
10. End of activity.

Observing the participants while they were accessing LIASE and monitoring their brain activity in real time clarified aspects of the individuals' efforts to learn in a virtual tool. There was a convergence between the participants' responses in the IMI and the monitoring of mental performance metrics observed when accessing the proposed learning script. In this sense, the performance metrics recorded represent what each participant expressed when reporting the effort spent on the process, the attention mobilized and the interest that LIASE motivated.

The mental state of engagement and interest was associated with the participant's report of enjoyment and immersion during access to LIASE. These elements are fundamental to the significance of learning and activation of the areas responsible for emotion and significance and selection of events and respective memories that consolidate learning.

The mention of the fun activity is consistent with the values presented in the “interest” performance metric. The results of the performance metrics indicate areas of the brain mobilized and linked to the limbic system, especially the amygdala, which receives and interprets external stimuli, giving them emotional meaning, mobilizing attention and long-term memory.

Most of the participants felt relaxed when carrying out the proposed activity, which confirms the results perceived by the performance metrics and responses obtained from the IMI.

Table 3

Mental Performance Metrics during Learning Activities - Participant 8

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	45	50	36	43	–	33	24	41	48	48
Excitement	72	53	28	72	–	33	37	70	56	24
Focus	37	39	29	30	–	33	26	36	43	36
Interest	35	33	35	37	–	40	38	37	46	47
Relaxation	11	12	21	22	–	27	26	20	34	29
Stress	19	21	29	28	–	30	32	26	31	30

Source: The authors.

Table 4

Mental performance metrics during learning activities – participant 16

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	–	39	41	43	43	36	48	55	49	59
Excitement	–	59	67	66	66	71	53	36	43	59
Focus	–	32	31	25	25	18	36	29	45	40
Interest	–	62	55	59	59	70	46	41	67	60
Relaxation	–	18	24	30	30	40	28	35	35	35
Stress	–	28	29	34	34	35	32	37	35	38

Source: The authors.

When comparing the data, it was clear that, both from the IMI report and the performance metrics monitored by the EEG, the participants had their attention mobilized in sufficient quality and depth to carry out the proposed activities and experience the sensation of immersion, with the feeling of losing the perception of time. It is therefore possible to have indications that the learning process took place during access to the virtual laboratory.

4. Conclusions

It was concluded that the study achieved the proposed objectives by developing and testing the virtual laboratory addressing the main biosafety topics: hand hygiene, use of PPE, types of isolation, COVID regulations, and classification of hospital waste. From the results obtained, it can be concluded that the study's innovative hypothesis —Can the mobilization of attention during the learning process be measured by EEG, through the monitoring of performance metrics and the Intrinsic Motivation Inventory – IMI?— was achieved, verifying that it was possible to obtain significant results in terms of the participants' attention during the learning process using the proposed methodology.

References

Andersen, S. J., & Hogan, L. (2019). Teaching advanced health assessment to nurse practitioner students using simulation. In *International Nursing Research Congress: Theory-to-Practice:* Catalyzing Collaborations to Connect Globally. Held (330), Alberta.

Bell, M. W. (2008). Rumo a uma definição de "mundos virtuais". *Journal of Virtual Worlds Research*, *1*, 1.

Cardoza, M. P. (2011). Neuroscience and simulation: An evolving theory of brain-based education. *Clinical Simulation in Nursing*, *7*(6), e205–e208.

Charland, P., Léger, P. M., Sénécal, S., Courtemanche, F., Mercier, J., Skelling, Y., & Labonté-Lemoyne, E. (2015). Assessing the Multiple Dimensions of Engagement to Characterize Learning: A Neurophysiological Perspective. *J. Vis. Exp*, *101*, e52627.

Corredor Camargo, J. A., Peña Cortés, C. A., & Pardo García, A. (2019). Avaliação das emoções de usuários em tarefas com feedback háptico utilizando o dispositivo Emotiv Insight. *INGE CUC*, *15*(1), 9–16.

Feiler, J. B., & Stabio, M. E. (2018). Three pillars of educational neuroscience from three decades of literature. *Trends in neuroscience and education*, *13*, 17–25.

Flick, U. (2013). *Introdução à metodologia de pesquisa*. Penso.

Fonseca, V. (2016). Importância das emoções na aprendizagem: Uma abordagem neuropsicopedagógica. *Rev. psicopedag*, *33*, 365–384. http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S0103-84862016000300014&lng=

Griol, D., J. M., M., & Callejas, Z. (2014). An approach to develop intelligent learning environments by means of immersive virtual worlds. *J. Ambient Intell. Smart Environ*, *6*(2), 237–255.

Harrison, T. (2013). *The emotiv mind: Investigating the accuracy of the emotiv epoc in identifying emotions and its use in an intelligent tutoring system* (Honours Report). University of Canterbury, New Zealand.

Langroudi, G., Jordanous, A., & Li, L. (2018). Music Emotion Capture: emotion- based generation of music using EEG. In *Emotion Modelling and Detection in social media and Online Interaction symposium at the AISB 2018 Convention*, (5), Liverpool.

Mcauley, E., Duncan, T., & Tammen, V. (1989). Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. *Research Quarterly for Exercise and Sport*, *60*(1), 48–58.

Murad, S. S. (2020). Brain involvement in the use of games in nursing education. *Journal of Nursing Education and Practice*, *7*(6), 90–94. http://www.sciedupress.com/journal/index.php/jnep/article/view/7977/6684

Ng, B., & Ong, A. K. K. (2018). Neurociência e ambiente de aprendizagem digital nas universidades: O que a pesquisa atual nos diz? *Revista da Bolsa de Ensino e Aprendizagem*, *18*(3), 116–131.

Nunes, W., & Zaro, M. A. (2019). *Neuroempreendedorismo: Como o cérebro identifica oportunidades de negócios inovadores*. EDUFARMA.

Rosat, R. M., Timm, M. I., Zaro, M. A., Meireles, L. O., Spindola, M., de Azevedo, A. M. P., & Bonini-Rocha, A. C. (2010). Emergência da neuroeducação: A hora e a vez da neurociência para agregar valor à pesquisa educacional. *Ciências & Cognição*, *15*(1), 199–210.

Sloan, D., & Norrgran, C. (2020). A Neuroscience Perspective on Learning. *Chem. Eng*, *50*(1), 29. https://journals.flvc.org/cee/article/view/87714/84511

Soto, V. J. (2013). Which instructional design models are educators using to design virtual world instruction? *Journal of Online Learning and Teaching*, *9*(3), 364.

Sportsman, S. (2021). Student engagement and the brain. *Collaborative Momentum Consulting.* https://collaborativemomentum.com/2018/05/22/student-engagement-and-thebrain/#more-2301/

Strmiska, M., Koudelková, Z., & abíková, M. (2018). Measuring brain signals using emotiv devices. *WSEAS Trans. Syst. Control*, *3*, 537–542

Tarouco, L. M. R., Da Silva, P. F., & Herpich, F. (2020). *Cognição e aprendizagem em mundo virtual imersivo* [recurso eletrônico] (L. M. R. Tarouco, P. F. da Silva, & F. Herpich, Eds.; 2 Ed.) [coordenado pela SEAD/UFRGS]. Editora da UFRGS.

Tokuhama-Espinosa, T. N. (2008). *The scientifically substantiated art of teaching: A study in the development of standards in the new academic field of neuroeducation (mind, brain, and education science).* [Tese de Doutorado, Programa de Pós-Graduação em Educação, Capella University, Minneapolis, Minesota]

Tsai, Y. C., Lin, G. L., & Cheng, C. C. (2021). Work-in-Progress-Development of Immersive Nursing Skills Learning System and Evaluation of Learning Effectiveness. *International Conference of the Immersive Learning Research Network (iLRN),* 7 Ed., 1–3.

Wang, Q., & Sourina, O. (2013). Real-time mental arithmetic task recognition from EEG signals. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *21*(2), 225–232.

Xu, J., & Zhong, B. (2018). Review on portable EEG technology in educational research. *Computers in Human Behavior*, *81*, 340–349.

Yang, X., Li, Y., Wang, L., & Li, D. (2018). Development and Application of Nursing Operation Virtual Simulation Training System. *International Conference on Engineering Simulation and Intelligent Control (ESAIC),* 2018.

Zaro, M. A., Arosat, R. M., Meireles, L. R. O., Marilda, S., & Azevedo, A. (2010). Emergência da neuroeducação: A hora e a vez da neurociência para agregar valor à pesquisa educacional. *Ciências & Cognição*, *15*(1), 199–210.